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Richard I. Macphail , Paul Goldberg
Excerpt
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Applied Principles from Geology and Soil Science

1.1 INTRODUCTION

Soil micromorphologists now working in archaeology are potentially in a much better position than they were during the 1950s through to the 1980s (Cornwall, 1953; Courty et al., 1989; Limbrey, 1975; Romans and Robertson, 1975a, 1983b). In fact, there has been a "spectacular increase" in the numbers of papers in archaeology (and paleopedology) toward the end of the last century (period analyzed spanned 1900–2000; Stoops, 2014). This is in part the result of a continually accumulating database, as ever more sites employ soil micromorphology. This also reflects the increasing numbers of workers and complementary techniques (e.g., micro-FTIR, EDS, microprobe), and publications in refereed journals and volumes in this field. Other important stimuli to the more accurate employment of soil micromorphology are experiments, the collection of reference materials, and the development of a Working Group (in Archaeological Soil Micromorphology) where both students and experienced workers interact. The International Working Group began with a small workshop at the Institute of Archaeology, University College, London in 1990, and has continued to the present day with meetings in 2013 at Cambridge (UK) and Basel (Switzerland), and in 2014 at Amersfoort (The Netherlands) (Arpin et al., 1998; Macphail, 2014a, 2014c). It can be noted that a recent survey of Working Group attendees at a number of venues, and which included the testing of workers with a wide span of experience (from trainee students to senior researchers), found a common weakness in their background of geological training, presumably mainly due to students often having a dominantly archaeological developmental path (Ruth Shahack-Gross, Basel workshop 2013, pers. comm.) (Shahack-Gross, 2015). By contrast, senior researchers more often had a training and postdoctoral involvement in earth sciences. Chiefly, the Basel meeting concluded that workers need to develop their understanding of the geological context of their sites as a first step in any investigation, hence one *raison d'être* for this book, and our previous work (Goldberg and Macphail, 2006b).

Moreover, this application of soil micromorphology to archaeology (geoarchaeology), thus has its basis in the earth sciences, primarily soil science and geology. The former includes both fundamental soil science principles (Brady and Weil, 2008; Duchaufour, 1982) and developments in soil micromorphological description and the characterization of pedological and geomorphological processes, as recognized at the microscale (Bullock et al., 1985; Courty et al., 1989; Stoops, 2003; Stoops et al., 2010). It can be reiterated here, however, that many of the developments in the geoarchaeological study of anthropogenic soils and sediments has come from an experimental, reference, and site-study database (see Section 1.7). Associated investigations may also include soil science and geology, with the latter involving sedimentology, and igneous and metamorphic petrology, for example. Mineral petrology and identifications (now often by X-ray spectrometry) is mainly a focus of ceramic provenancing and associated forensic investigations (Pirrie et al., 2004; Quinn, 2013; Spataro, 2002). There is, unfortunately, no room in this chapter to include a full geological and soil science background. This has already been achieved in previous volumes (Courty et al., 1989; Goldberg and Macphail, 2006b). In this introductory chapter we have been forced to be extremely selective, but this is hopefully offset by the large number of reference sediment and soil types described and illustrated throughout this book, and the numerous specialized references that we have noted.

The chapter begins with an introduction to some sediment and rock types found in the book's case studies, which are given alongside some of the sedimentary environments and associated geological/geomorphological processes that are the most likely to be encountered by geoarchaeologists (see Table 1.1, in which some studied sites are listed, and Chapter 5 where terrestrial – fluvial, slope, and mass-movement – processes are described according to case studies). The important concepts of Facies and Microfacies are briefly introduced alongside some sediment type examples of special concern in this book. The latter include calcareous formations and what are termed as Transitional Environments in Tables 1.2 and 1.3. Soils and pedological processes are also only briefly introduced alongside some site examples (Table 1.4), because again numerous soil types are dealt with in detail in Chapter 4. Other site examples from around the world are given throughout the book; for example, desert soils and paddy soils are viewed in the context of agriculture in Chapter 9, while a tropical soil formation example is given in Chapter 12. It is also important to note that soil micromorphologists working in archaeology are no longer totally reliant

Table 1.1. *Common sedimentary environments and their subdivisions and site examples found in this book*

Marine environments	Transitional environments	Continental environments
Open shelves	Lagoons and bays (Boxgrove, UK; Guantanomo Bay, Cuba; Playa Vista, USA)	Mountain ranges (Chisone Valley, Italy)
Sheltered shelves (Ommels Hoveo, Denmark)	Deltas (Playa Vista, USA; Oslo, Norway)	Intermontane (Pratto Mollo and Uscio, Italy; Upland Norway, Sweden, England and Wales)
Inland seas (Oslo Fjord, Norway)	Beaches (Marco Gonzalez, Belize; Guantanomo Bay, Cuba; Boxgrove, UK; Gibraltar caves)	Troughs (Olduvai Gorge, Tanzania)
Continental slopes	Mangrove swamps (Marco Gonzalez, Belize)	Deserts (Cactus Hill, Dona Ana and Las Capas, USA; Negev Desert, Israel)
Pelagic oceans	(Also tidal flats, sand bars, estuaries, saltmarsh) (Blackwater, Crouch, Humber, Severn and Thames Rivers; Wallasea Island, Essex, UK; Marco Gonzalez, Belize)	River valleys (Imjin and Hantan Rivers, Korea; Liujian River, Hui zui, China; River Lågan, Norway; Eden, Humber, Itchen, Nene, Thames Rivers, UK)
Deep-water trenches		Lakes and ponds (Bargone, Italy; Berkhampstead, Boxgrove, UK)
Coral reefs (Marco Gonzalez, Belize)		Alluvial plains (Ecsegfalva, Hungary; Magura and Bordușani, Romania)
		Coastal plains (Djibouti)

Source: Modified from Kukal, 1971; Reineck and Singh, 1986 and as employed in Courty et al. (1989).

Table 1.2. *Calcium carbonate ($CaCO_3$) formations, features, and inclusions*

Type	Common environment of formation	Common characteristics and comments
Travertine[1]	Calcareous springs, lake edges	Often bedded, composed of calcite crystals – used for construction (e.g., Herodian aqueduct, Jordan Valley)
Tufa[2]	Calcareous springs, rivers	Porous, mixture of micritic and microsparitic calcite, with embedded fine to coarse plant fragments – used for construction (easily split for wall and floor slabs)
Marl[3]	Ponds, lakes, and lagoons (and marine)	Generic term for impure calcium carbonate (~35%–65%), which may contain silt, sand, and clay (~35%–65%); calcareous microfossils can also be present (molluscs, charophyte [green algae] remains, ostracods).
Calcrete[4]	Terrestrial soils and sediments	Massive cementation of soils and regoliths by groundwater rich in dissolved $CaCO_3$
Speleothem[5]	Caves, karstic caves	Stalactites (hanging down), stalagmites (growing upward), dripstone and moonmilk (biochemically formed on cave walls); cemented cave breccias.
Biogenic calcite A[6]	Soils and sediments	Calcite root cell pseudomorphs (rhizoliths), needle fibers (pseudomycelia) and other biogenic structures formed in calcareous environments. Such phenomena can occur in decalcified soils if roots penetrate through to an underlying calcareous substrate/groundwater.

Table 1.2. (*cont.*)

Type	Common environment of formation	Common characteristics and comments
Biogenic calcite B[7]	Plant and faunal remains	Calcite (altered calcium oxalate) residues in leaf, root, and wood (charcoal) remains; herbivore dung spherulites; ashes and recemented ashes, slug (Arionid) plates, earthworm granules, land snails, freshwater and marine molluscs; microfossils such as ostracods and some foraminifera.

1: Courty et al., 1989, 99–100; Goldberg and Macphail, 2006, 24–26

2: Courty et al., 1989, 99–100; Goldberg and Macphail, 2006, 24–26

3: Pettijohn, 1975

4: Courty et al., 1989, 174–179; Durand et al., 2010

5: Courty et al., 1989, 99–100; Gillieson, 1996

6: Becze-Deák et al., 1997; Durand et al., 2010

7: Brochier, 1996; Brochier and Thinon, 2003; Brochier et al., 1992; Canti, 1998a, 1999; Canti, 1998b; Durand et al., 2010; Karkanas et al., 2007; Shahack-Gross, 2010; Shahack-Gross et al., 2014

on geology and soil science to help them understand sites, as was the case in the 1980s. This is because of the major and continuing development of experimental and reference databases (see 1.7–8; see also Chapter 7). The origins and breadth of these is introduced, while relevant examples are given in detail for instance in Chapters 4 (effects of soil burial), 9 (ancient cultivation), and 10–11 (use of space and animal husbandry). Lastly, while numerous textbooks cover field work and sampling, this book focuses on the various strategies and tactics applied to various site types, from Quaternary sites to those of complex societies (1.9).

Table 1.3. *Coastal environments*

Environment	Sediment type	Character	Comments
High energy cliff base and wave cut platform	Boulders derived from cliff rock and/or boulders within cliff (e.g., conglomerates, till)	E.g.: interstitial, massive and laminated coarse and very coarse sands, gravel and cobbles; sometimes calcitic with shell fragments.	Relict deposits can be decalcified with laminae picked out by iron-panning; may occur as cemented conglomerates.
High energy beach zone	Cobbles, gravel, and sands	Generally well-sorted fine or medium or coarse sands in swash zone; very coarse sands, gravels, and cobbles at top of beach.	E.g: coarsely bedded well-sorted fine sands with bands of micritic clay-size material (detrital chalk) with very high interference colors (only 3–4% clay in decalcified samples). Chalk fossils, chalk fragments present; Coarse (2–3 to 20–30mm) burrows (polychaete worms and molluscs); micro-faulting. (Boxgrove, West Sussex, UK) Inundation beach (Marco Gonzalez, Belize) (Note, intense bioworking leads to massive structured "poorly sorted" mixed sands and clay-size material) (Guantanomo Bay beach, Cuba)
Coastal dune area	Cross-bedded and massive sands	Well-rounded and well-sorted sands; shell fragments	When occurring in coastal caves, can be interdigitated with silty clay of terrestrial phreatic origin (Vanguard Cave, Gibraltar)

Low energy estuarine mudflat and lagoonal environments	Silts and clays; marls; sometimes with organic content	Finely laminated silts and clays, massive to finely laminated marls (Secondary minerals can include gypsum, jarosite, pyrite, and siderite)	Horizontally laminated; can include “coarse” (fine sand) along with silt and clay laminae, some of which are rich in detrital organic matter. (Marco Gonzalez, Belize; Guantanomo Bay lagoon, Cuba; The Stumble, River Blackwater and Stanford Wharf, River Thames, Essex, UK, and Boxgrove, West Sussex, UK) Unweathered sediments can be calcitic, and sometimes lagoonal marls form (Playa Vista, USA).
Saltmarsh, mangrove, and other swampland	Silts and clays (“muds”); commonly with organic content.	Often massive, but with relict laminae at depth below bioworking level. (see above for possible secondary minerals)	Fresh deposits are likely to be calcitic, laminated, and with detrital organic matter content; local plant remains (marsh, swamp plants, and invasive woodland possible); probable freshwater flushing, ripening effects, and secondary mineral formations, alongside bioworking features (Wallasea Island, River Crouch, Stamford Wharf, River Thames and Goldcliff, River Severn, UK)

Note: See Table 6.3 for post-depositional effects on inundated sites and soils.

Source: After Goldberg, 1979; Goldberg and Macphail, 2006; Reineck and Singh, 1986.

Table 1.4. *Soil horizons, soil types, and studied examples*

Common usage horizon/ soil type (FAO, UK and USA)	Soil character (after Goldberg and Macphail, 2006, table 3.2)	Studied example
L (Litter)/Oi/O1/Mull topsoil (cf. Mollic epipedon and Umbric epipedon) and LF (Fermentation)/ Oe/O2/Moder topsoil (essentially well-drained conditions)	(L) High biological activity; only accumulation of plant fragments. (F) Moderately low biological activity; accumulation of excrements of soil fauna and decomposing plant fragments below L.	Overton Down (Grassland Rendzina) and Wareham (Heathland Podzol) Experimental Earthworks, UK Bagböle Experimental Farm, North Sweden (Boreal Podzol) Marco Gonzalez, Belize (Tropical woodland surface soil)
Laminated mull (Barrat, 1964) (essentially poorly drained conditions)	(L-F) Interlayered, often horizontally oriented plant remains (e.g., grass, sedge) and patchy invertebrate mesofauna excrements.	Gleyed coastal topsoils at Viking Gokstad Ship Burial Mound, Norway and Wallasea Island Experiment, UK; Roman Hadrian's (turf) Wall, UK
LFH (Mor "humus") ~Oa/O2	(H) Very low biological activity (e.g., bacteria); accumulation of amorphous organic matter termed humus (H) below, L and F.	Neolithic Stonehenge Quarry, Bronze Age West Heath (Heathland Podzol), Early Iron Age Hengistbury Head (Oak podzol), Bronze Age Fan Foel and Dark Age "Short Dykes" Powys (Upland grassland), UK
Peat/~Oa)/O/ (Histic epipedon)	(O) Absolute accumulation of organic matter because waterlogging inhibits biological breakdown of organic matter.	Middle Pleistocene (Boxgrove) and Holocene (Goldcliff) coastal peats, fen and fen carr peats (Innova Park, Pilgrims, Sutton Gault, Thames Crossings), UK; Pratto Mollo basin and Bargone lake peat, Italy.

Table 1.4. (*cont.*)

Common usage horizon/ soil type (FAO, UK and USA)	Soil character (after Goldberg and Macphail, 2006, table 3.2)	Studied example
Humic topsoil (A1h) (Mollic epipedon and Umbric epipedon; Mollisols include grassland prairie soils and chernozems)	(A) Accumulation of organic matter in the mineral soil (along with associated nutrients of N, K, and P); focus of biological activity and organic matter turnover (oxidation and alteration – "fermentation" leads to maghemite iron and enhanced magnetic susceptibility)	See Mull; Neolithic Belle Tout, Easton Down, Hazleton, Maiden Castle, Windmill Hill, UK; Ecsegfalva, Hungary
Plaggen "Ap" (Cultosol) Anthropic epidpedon	Over-thickened (0.40–1.0 m) humic topsoil developed through additions of manure, turf, household and settlement waste. (e.g., since AD 1000 in Holland)	Roman Wittington Ave, medieval Whitefriars, UK; Iron Age Bjornstad, Hørdalsåsen, etc., Norway; early medieval Tours, France; Chisone Valley, Italy
Ap Ploughsoil/ Cultivated A/Arable topsoil	Topsoil, mechanically homogenized to depth of plough share (*c.* 0.40 m) or ard (e.g., 0.06 m); liable to loss of organic matter through oxidation; arable soils ameliorated by additions of organic manures, possibly since Neolithic.	Experimental Butser (UK) and Bagböle (Sweden) Farms, and modern Hazleton and Wallasea Island; Neolithic Easton Down, Hazleton and Kilham, Bronze Age Ashcombe Bottom and Phoenix Wharf, Roman Whitefriars, Saxon Oakley, Medieval Wolverhampton, modern Wallasea Island, UK; Viking Lindholm Høje, Denmark; Early medieval Büraburg, Germany; Iron Age-Viking Avaldsnes and Hesby, Norway

(continued)

Table 1.4. (*cont.*)

Common usage horizon/ soil type (FAO, UK and USA)	Soil character (after Goldberg and Macphail, 2006, table 3.2)	Studied example
A1h Pasture topsoil/ ~prairie/cf Mollic epipedon (Ap; includes both plough and pasture in USA)	Normally grass covered humic topsoil (cf Mull), with crumb over fine blocky microstructure; surface compaction, dung traces possible.	Modern Maiden Castle, Neolithic Belle Tout, Neolithic and Bronze Age Raunds, UK; Bronze/Iron Age Avaldsnes and Fevang nordre, Norway
Eb/Leached/eluviated upper subsoil horizon /Albic E (A2)(Argillic Brown Soil/Luvisol/ Alfisol)	Specifically eluviation of clay (along with cations, including iron; organic matter and phosphorus)	Prehistoric to Roman London and Whitefriars, Neolithic to Iron Age Raunds, UK; Huizui, China
Ea (Eag – when surface waterlogging)/Leached/ eluviated upper subsoil horizon/ Albic E (A2) (Podzol/Spodosol)	Eluviation of iron and aluminum (sesquioxides) (after acid breakdown of clay and mobilization by plant chelates)	Experimental Wareham, Bronze Age Chysauster, Hengistbury Head, West Heath, Dark Age Short Dykes, Wales; Hørdalsåsen, Norway
Bw subsoil horizon/ Cambic B (Brown Soil/ Cambisol)	General pedogenic alteration as indicated by weathering of minerals, structure formation, loss of carbonates, and clay formation, etc.	Neolithic Carn Brea
Argillic Bt subsoil horizon/Argillic B (Argillic brown soil/ Luvisol/Alfisol)	As above, but with illuviation of clay from overlying A2 horizon (clay translocation)	Neolithic to Bronze Age Raunds, Prehistoric to Roman London and Whitefriars, UK; Huizui, China; Bordușani, Romania
Bs/Bh/Bhs subsoil horizon/Spodic B (Podzol/Spodosol)	Illuviation of sesquioxides (Fe and Al) often with humus	Experimental Wareham, Neolithic Carn Brea, Bronze Age Chysauster, Hengistbury Head, West Heath, UK; Hørdalsåsen, Norway